Preliminary Investigation of Curved Liner Sample in the NASA LaRC Curved Duct Test Rig

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Outline

- **Background**
- **Aerodynamic Results**
  - Flow on M = 0.275
- **Acoustic Results**
  - Flow off
  - Flow on
- **Summary**

Purpose of the Curved Duct Test Rig

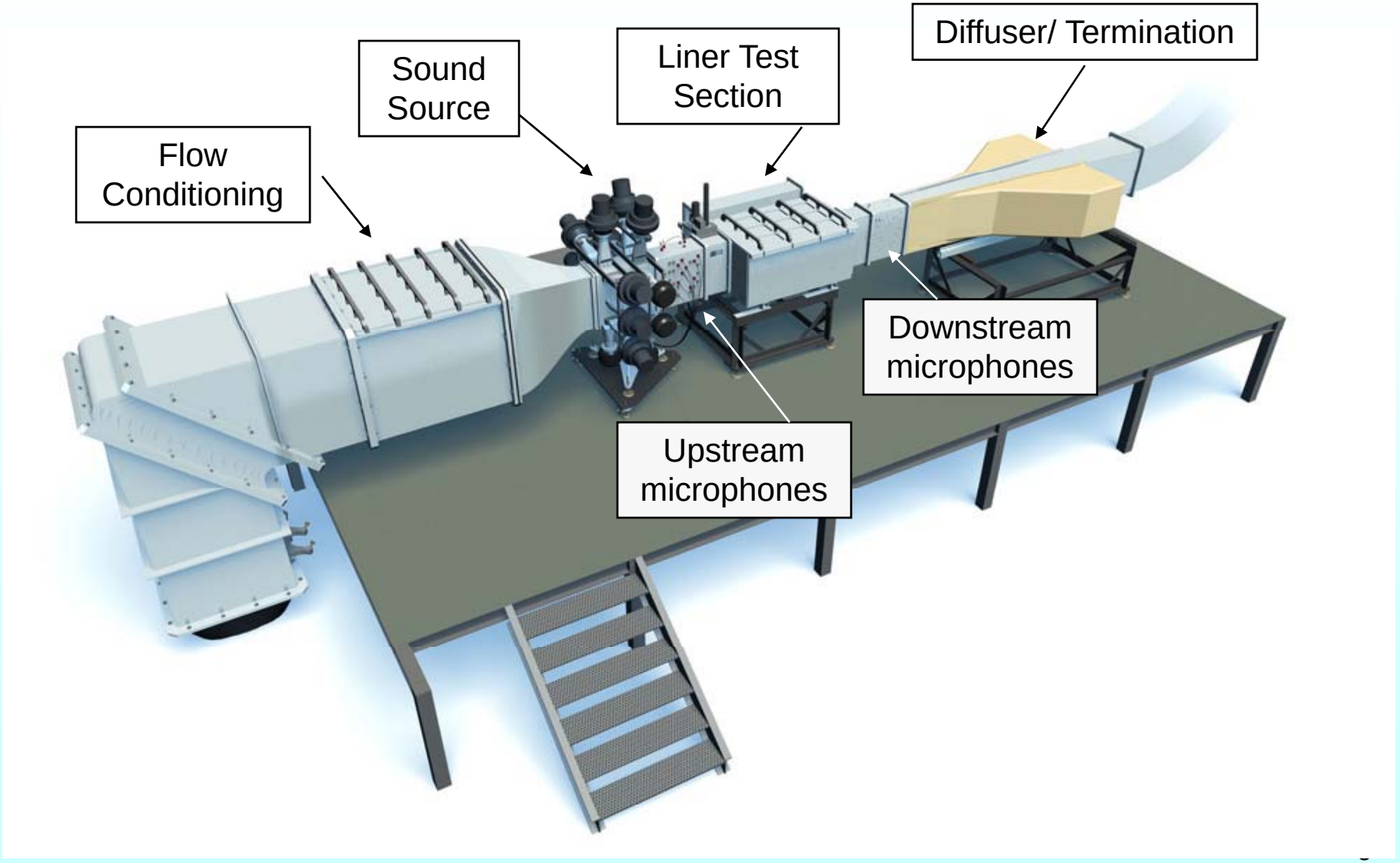
Develop capability to investigate acoustic and aerodynamic properties in ducts

- Large scale
- Flow rate to M = 0.275
- Higher order mode control
- Curved flow path
- Adaptable test section
- Flexible test configurations

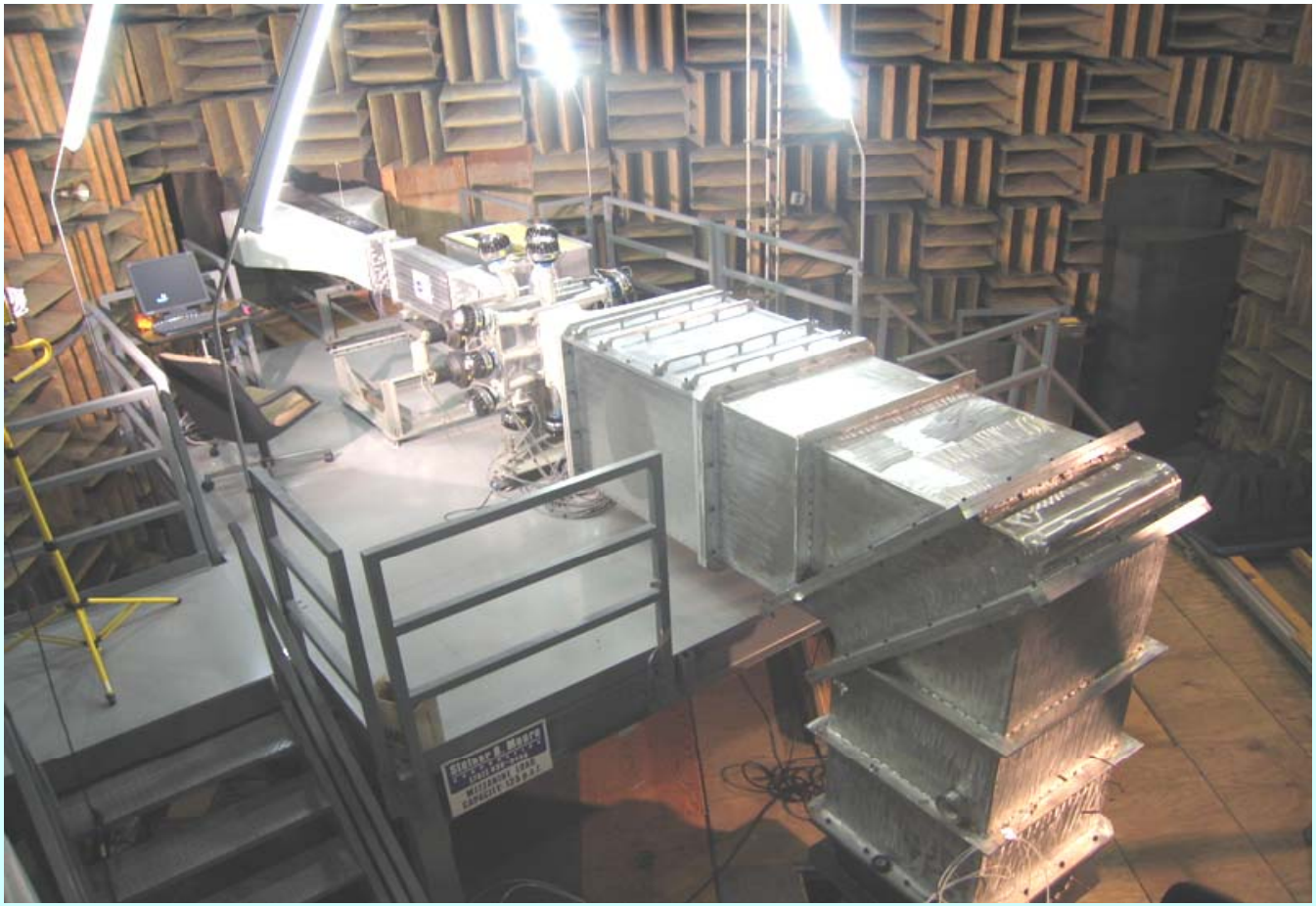
Development

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

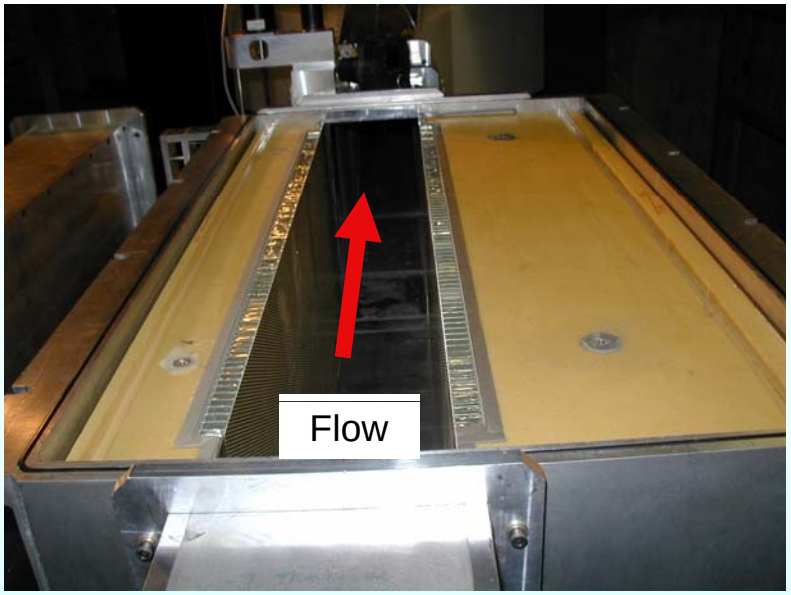
Curved Duct Test Rig



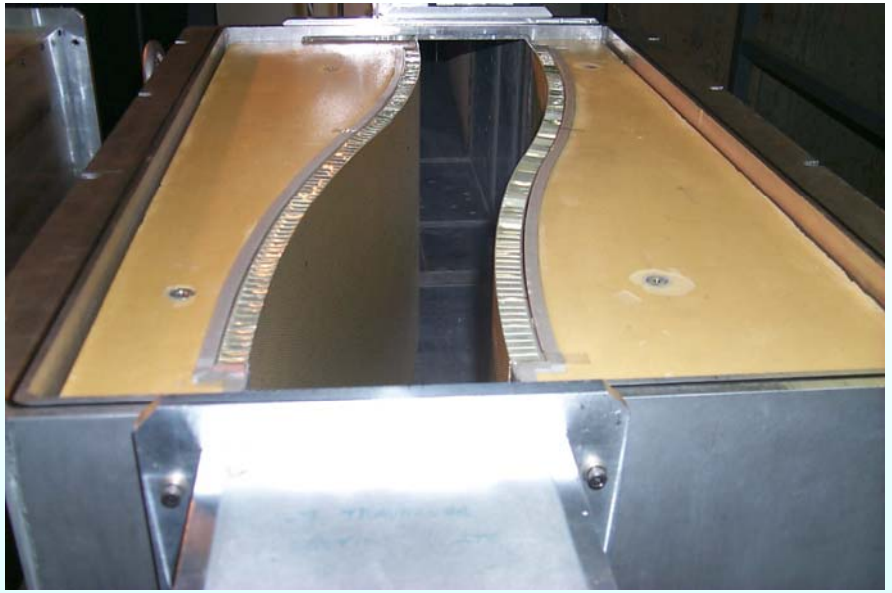
Curved Duct Test Rig (CDTR)



Test liner samples



Straight liner sample (L02S)



Curved liner sample (1 duct width offset) (L04S)

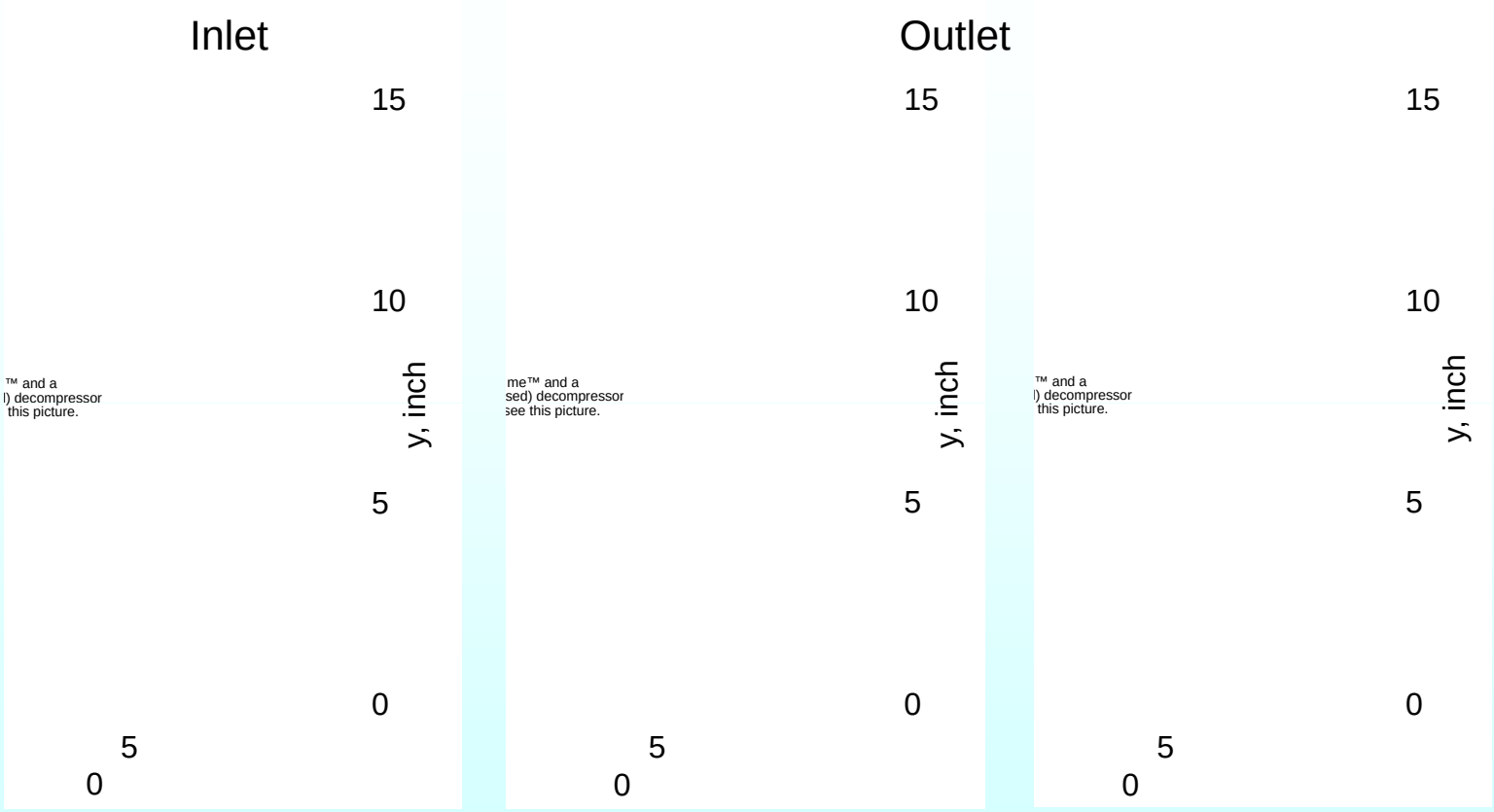
- **Liner Test Section**
  - 6 inch (H) x 15 inch (V) x 36 inch (A)
- **Liner Characteristics**
  - Core depth-0.75 inch
  - Perforate - 8.7% open area
  - Perforate thickness - 0.025 inch
  - Manufactured by Goodrich Aerostructures

Aerodynamic measurements

- **Measure properties at inlet and outlet of liner test section**
- **Data acquired**
  - Mean axial flow across duct
  - Boundary layer mean flow
  - Turbulence intensity
  - Flow angularity *
- **Liner Configurations**
  - Straight, hard wall (calibration duct) (L00H)
  - Straight, treated both sides (L02S)
  - Curved, 1D offset, treated both sides (L04S)

* - not reported here

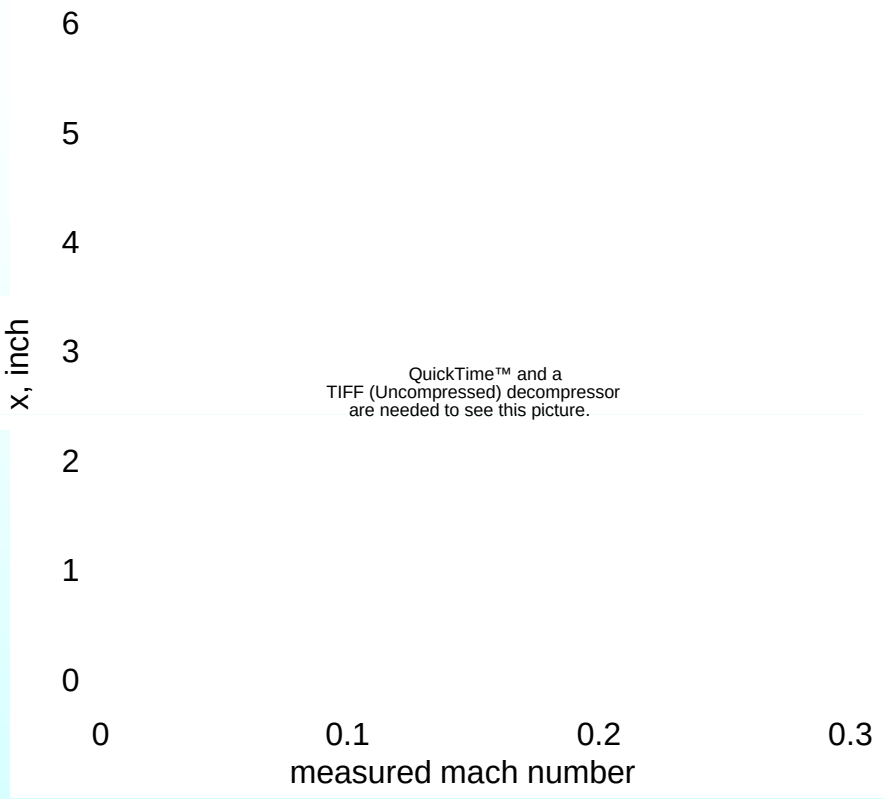
Local Mach number contours



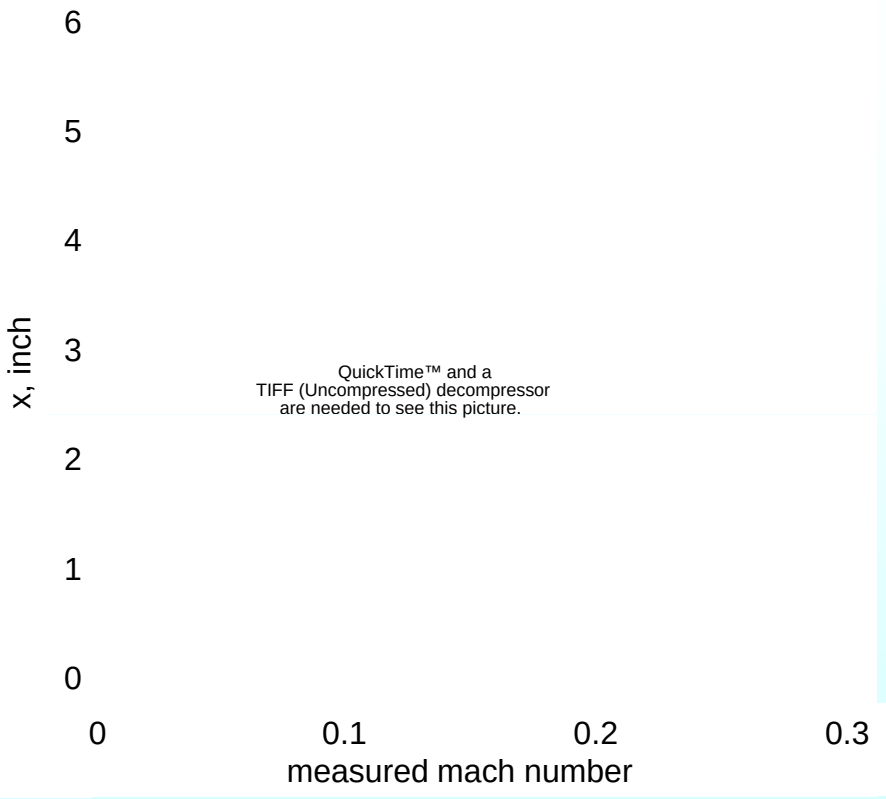
Straight, hard wall (L00H) Straight, treated (L02S) Curved -1D offset, treated (L04S)

- **Curvature thickens boundary layer and increases core flow slightly**

Boundary Layer - test section outlet



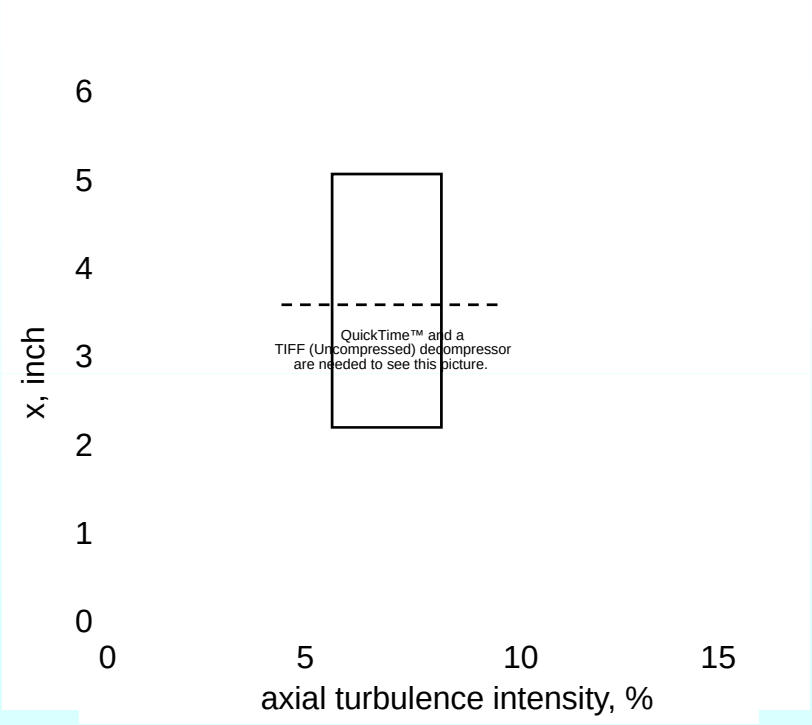
Y = 7.5 inch (mid duct)



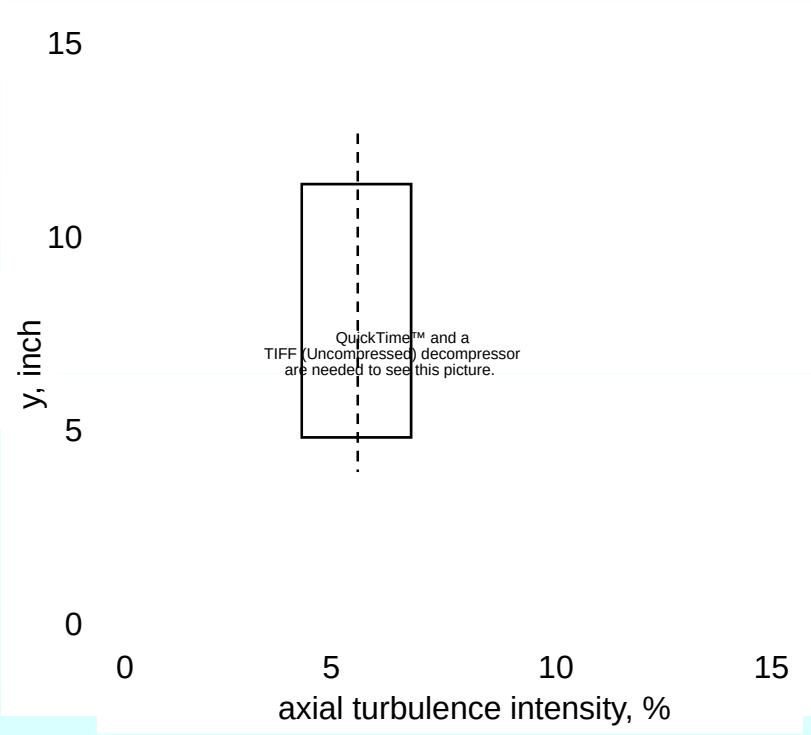
Y = 0.833 inch (bottom wall)

- **Curvature promotes development of secondary flow near corners**

Turbulence Intensity-test section outlet



Across duct width at y = 7.5 inch



Across duct height at x = 3.0 inch

- **Turbulence content not affected by wall acoustic treatment or duct curvature**

Acoustic testing configurations

- **Purpose of tests**
  - Evaluate effect of curvature
  - Evaluate effect of flow
  - Compare one side treated to both sides treated

Liner	Code	Flow	
		M = 0.000	M = 0.275
Straight Goodrich Liner-Both Sides Treated	L02S	F	P
Straight Goodrich Liner-Right Side Treated	L02R	F	P
1D Offset Goodrich Liner-Both Sides Treated	L04S	F	P
1D Offset Goodrich Liner-Right Side Treated	L04R	P	P

Acoustic test matrix

Full

	Propagating mode (V,H)												
Frequency	**(0,0)**	**(1,0)**	**(2,0)**	**(0,1)**	**(1,1)**	**(3,0)**	**(2,1)**	**(3,1)**	**(4,0)**	**(4,1)**	**(0,2)**	**(5,0)**	**(1,2)**
300													
400													
500													
600													
700													
800													
900													
1000													
1100													
1200													
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1900													
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2100													
2200													
2300													
2400													

Note: Cut-on frequencies based on 6Ó x 15Ó cross sectional area at 70̊F. 124 points.

Acoustic test matrix

Partial

	Propagating mode (V,H)												
Frequency	**(0,0)**	**(1,0)**	**(2,0)**	**(0,1)**	**(1,1)**	**(3,0)**	**(2,1)**	**(3,1)**	**(4,0)**	**(4,1)**	**(0,2)**	**(5,0)**	**(1,2)**
300													
400													
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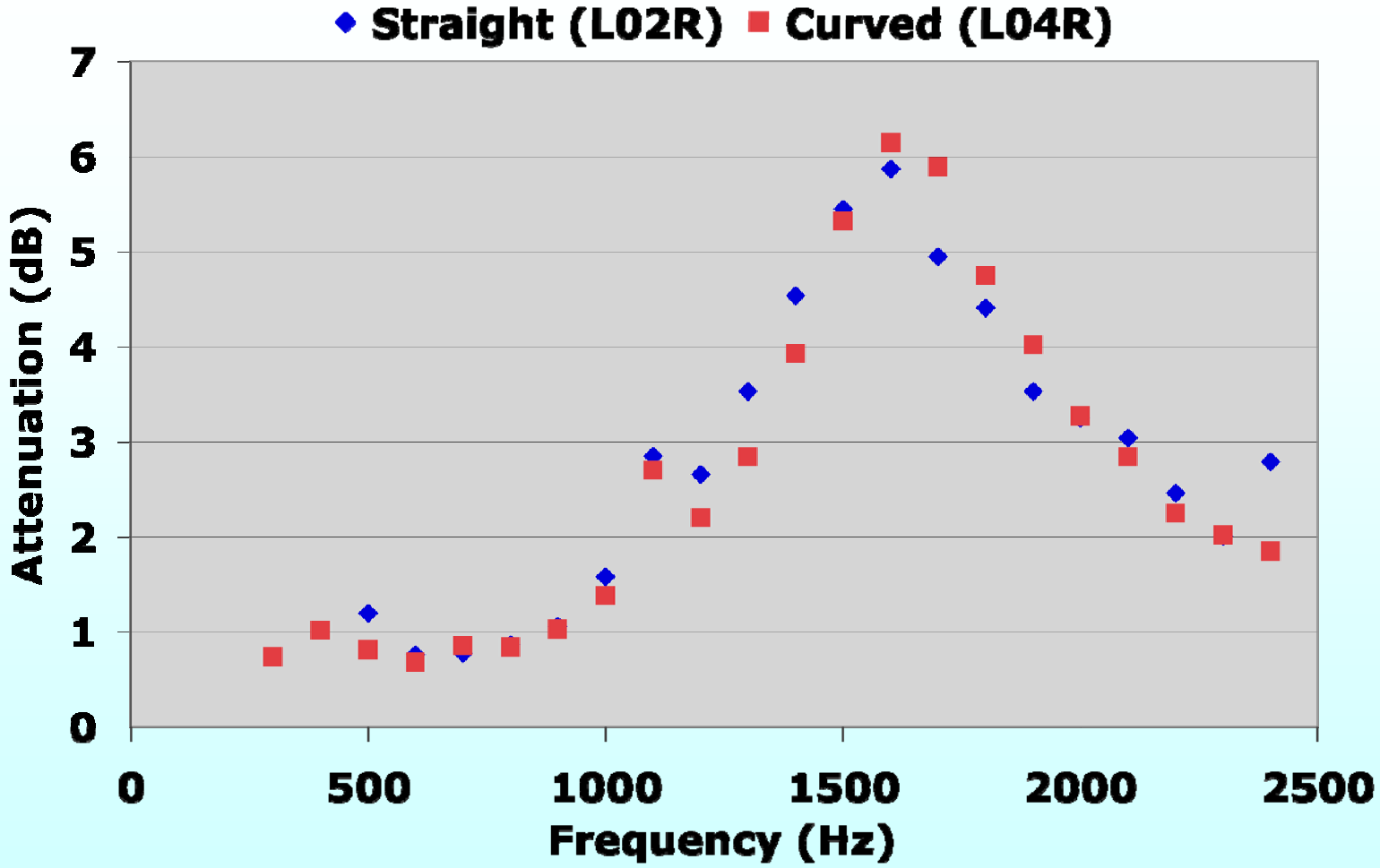
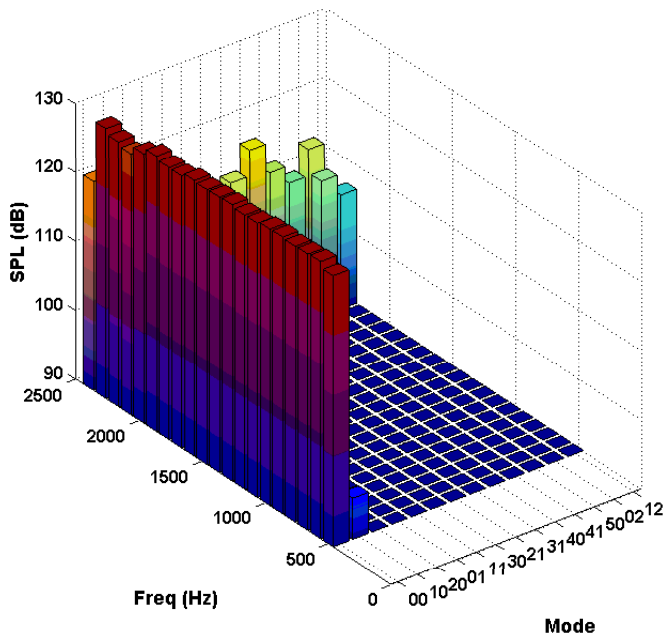
Effect of curvature-right wall lined



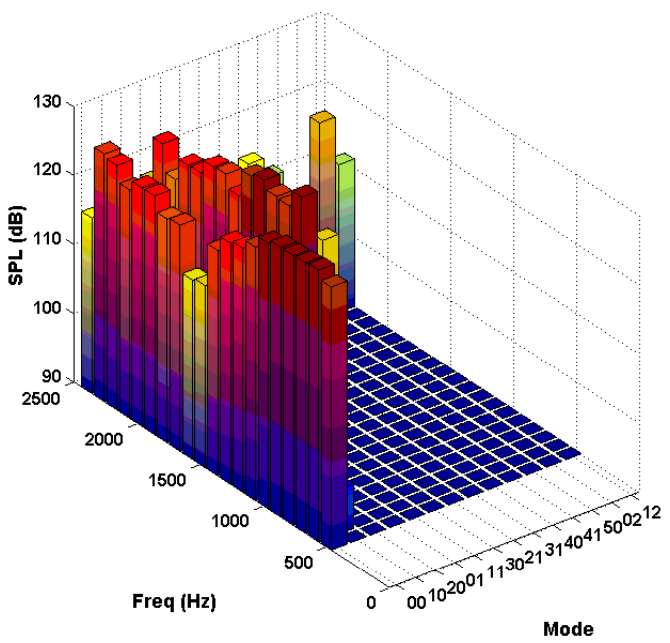
- Curvature has minimal effect on attenuation of plane wave generated in duct at no flow

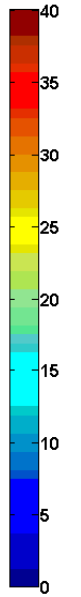
Mode scattering

Upstream



Downstream

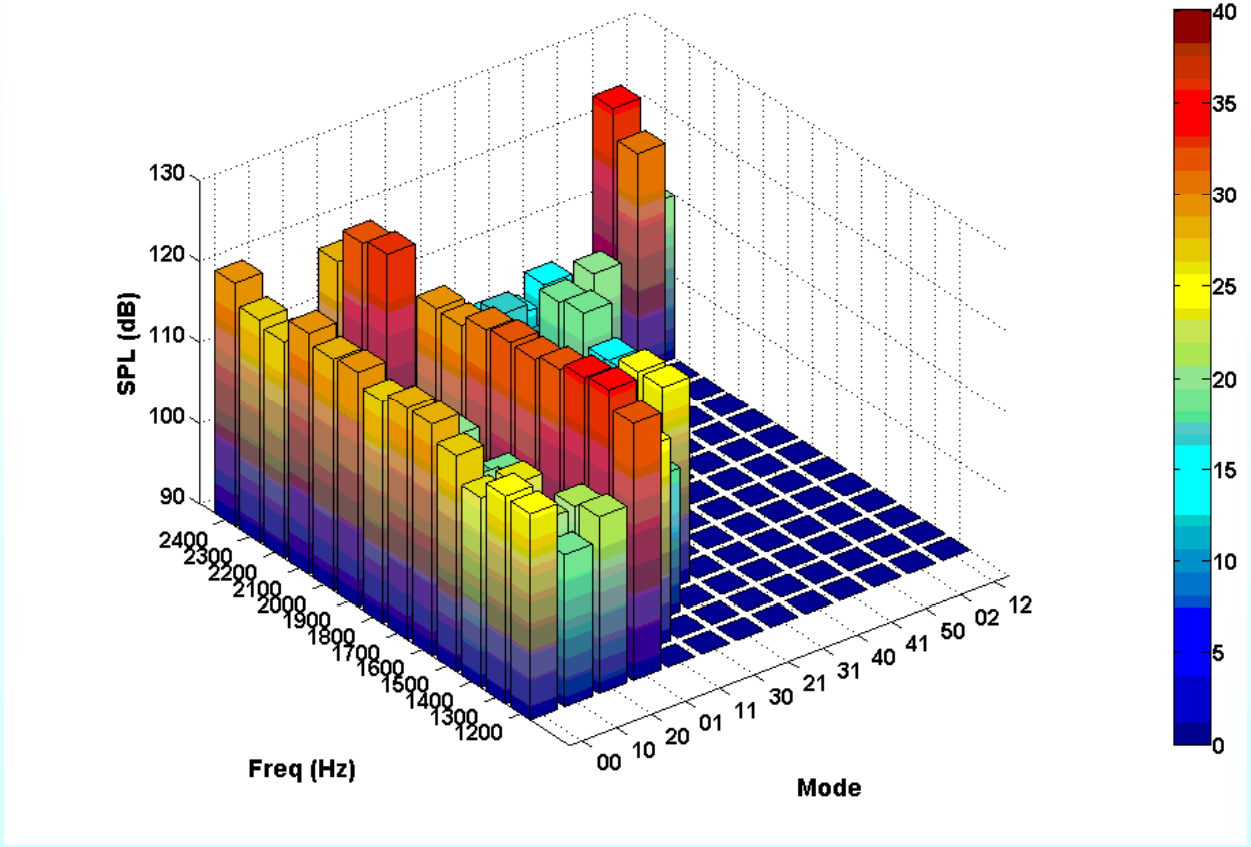




re 90 dB

- **Plane wave source, straight liner section, right wall treated (L02R)**
- **Plane wave amplitude reduced by as much as 18 dB by liner**
- **Horizontal 0-order mode scatters to horizontal 1-order mode**

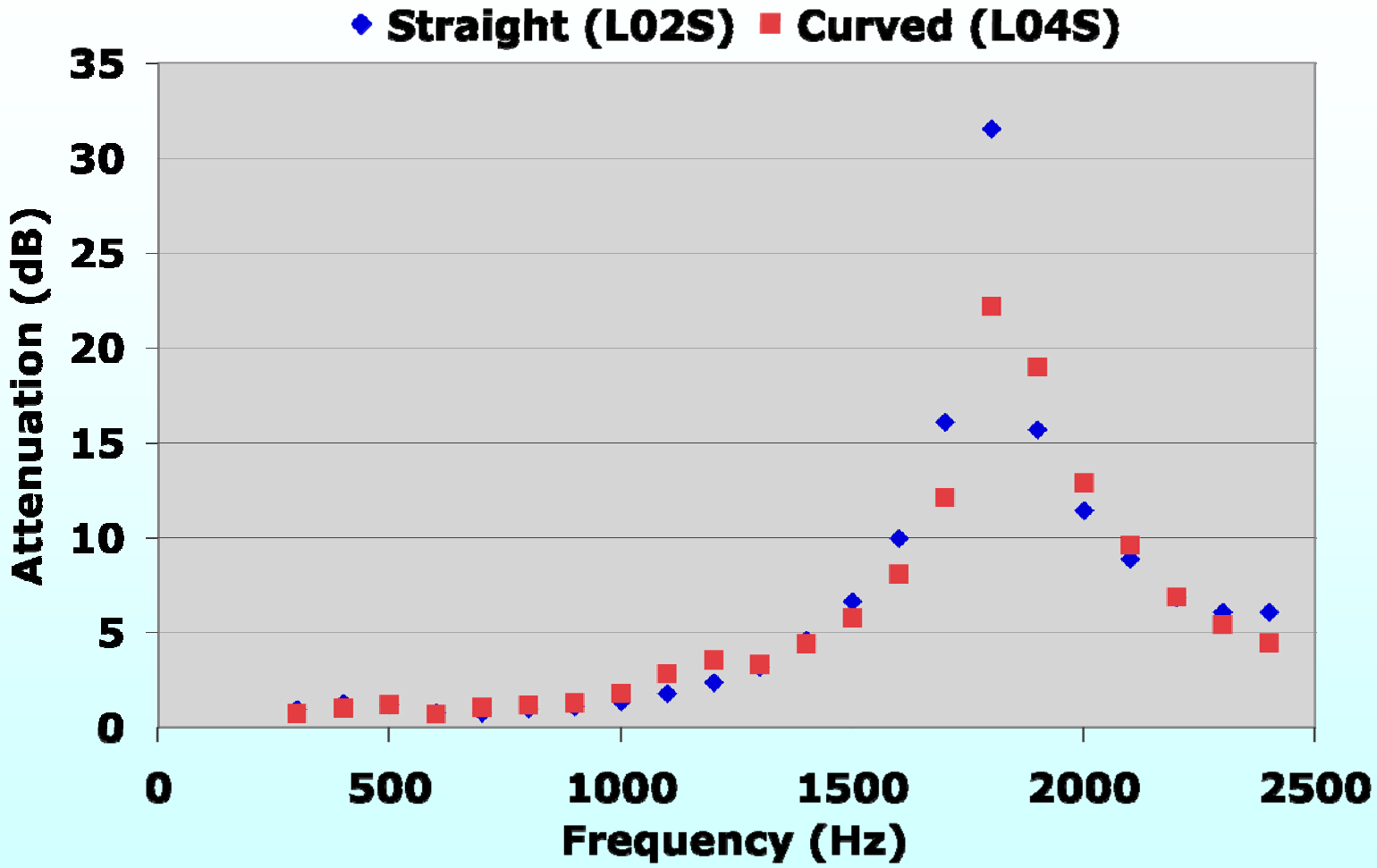
Mode scattering-continued



Mode distribution downstream, (0,1) mode generated in duct with curved liner, no flow

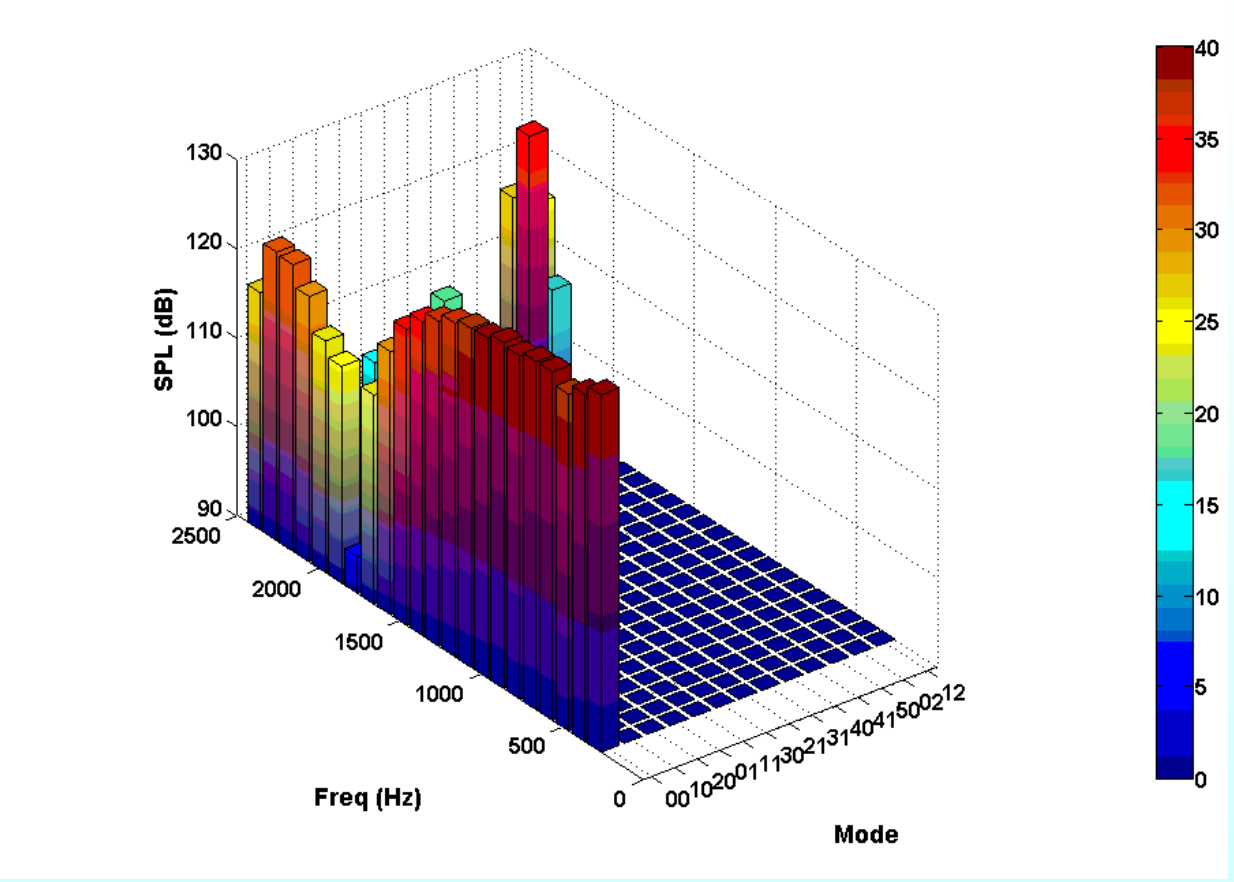
- **Horizontal order 1 modes scatter to lower energy state**

Effect of curvature-both walls treated



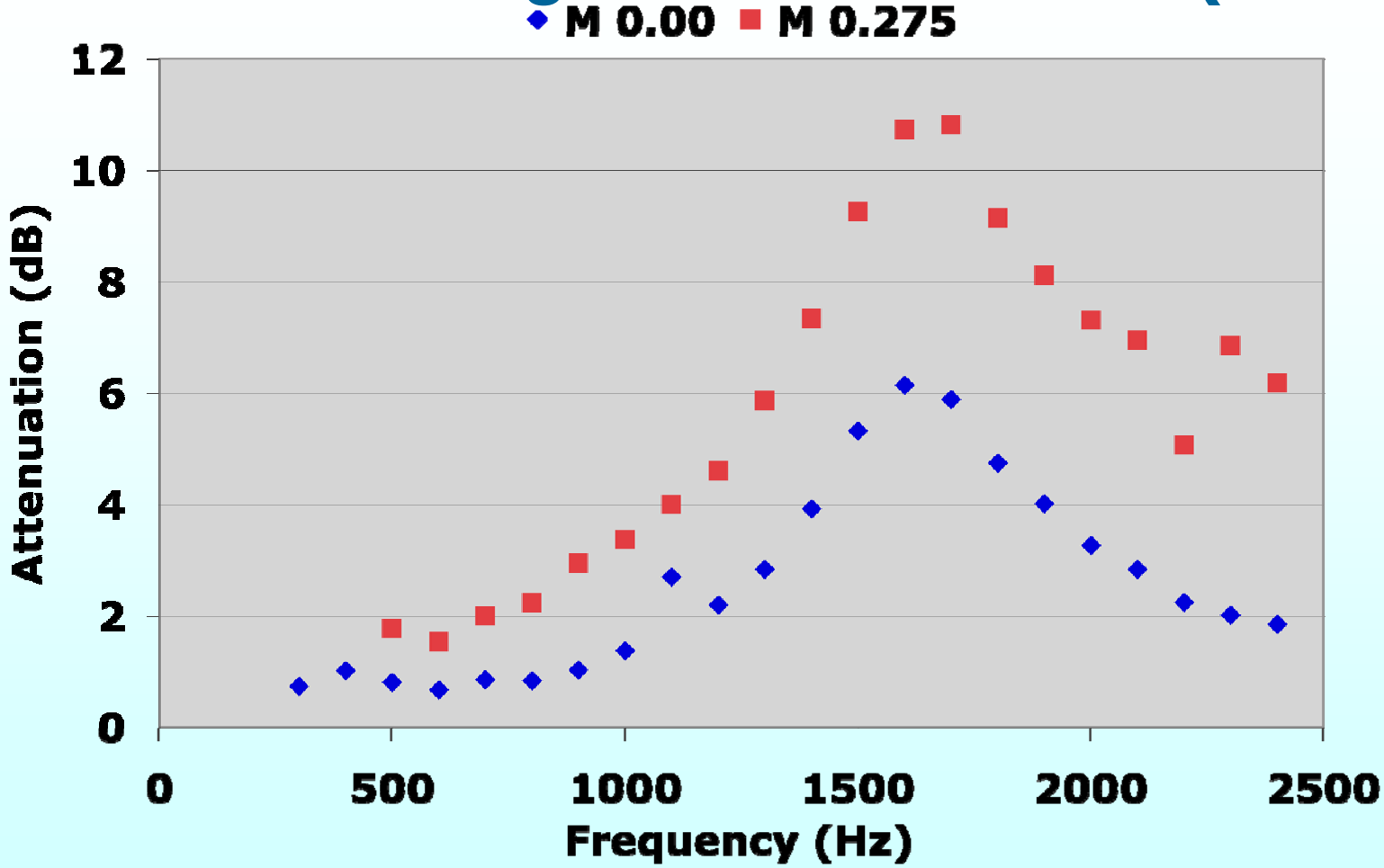
- Plane wave incident
- Curvature does not have large impact on attenuation

Mode Scattering-both sides treated



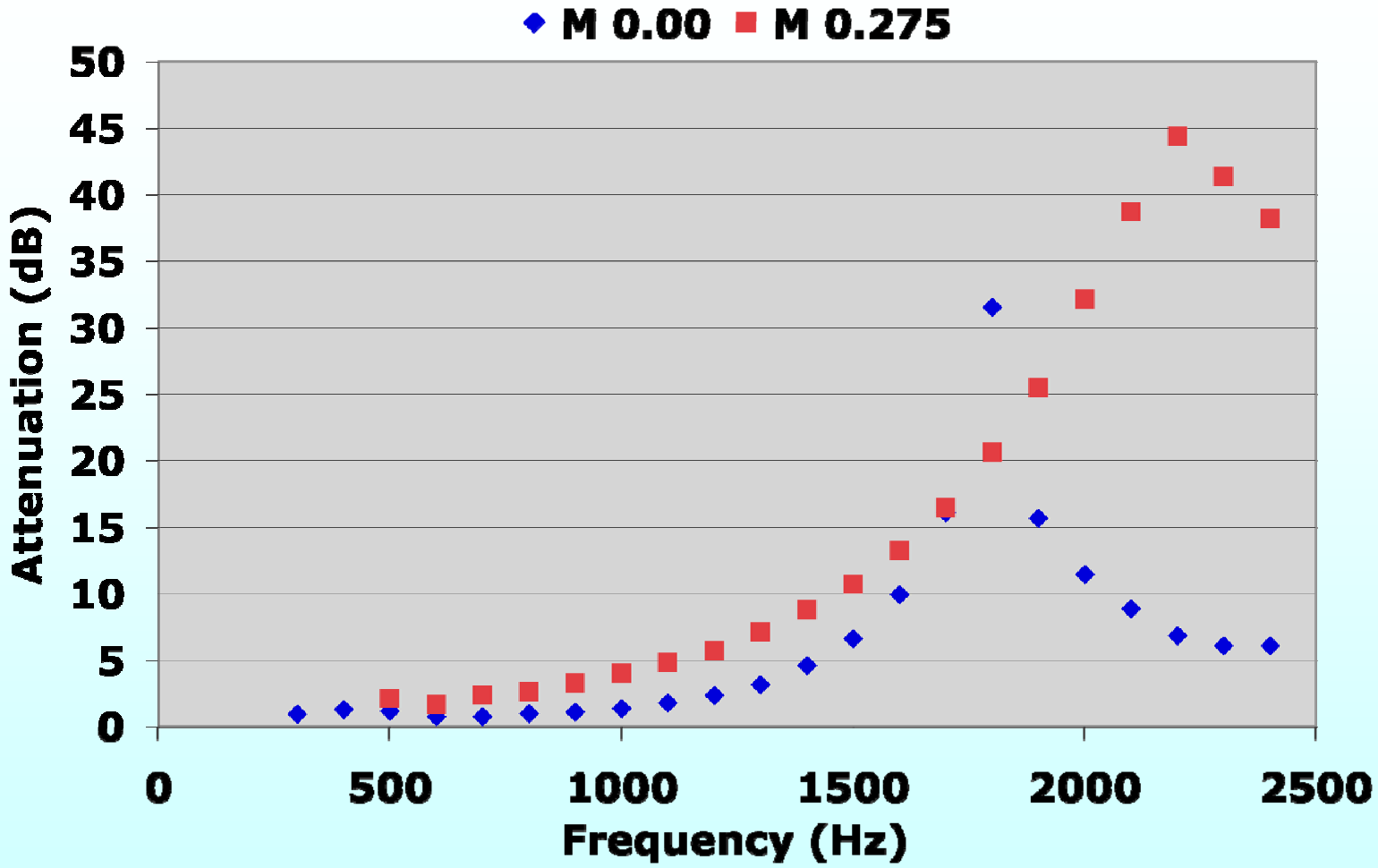
- **Mode scattering for plane wave incident is eliminated when both sides are lined**

Effect of flow- right side treated (L04R)



- Flow increases attenuation of plane wave by curved liner
- Peak shifted slightly toward higher frequency
- Similar result for straight liner (L02R)

Effect of flow-both sides treated



- Attenuation of plane wave generated in duct with Goodrich straight liner, both sides (L02S)
- Similar results for curved liner (L04S)

Summary

- Liner has minimal effect on turbulence or boundary layer growth in duct
- Curved duct sample attenuation is affected by mode scattering

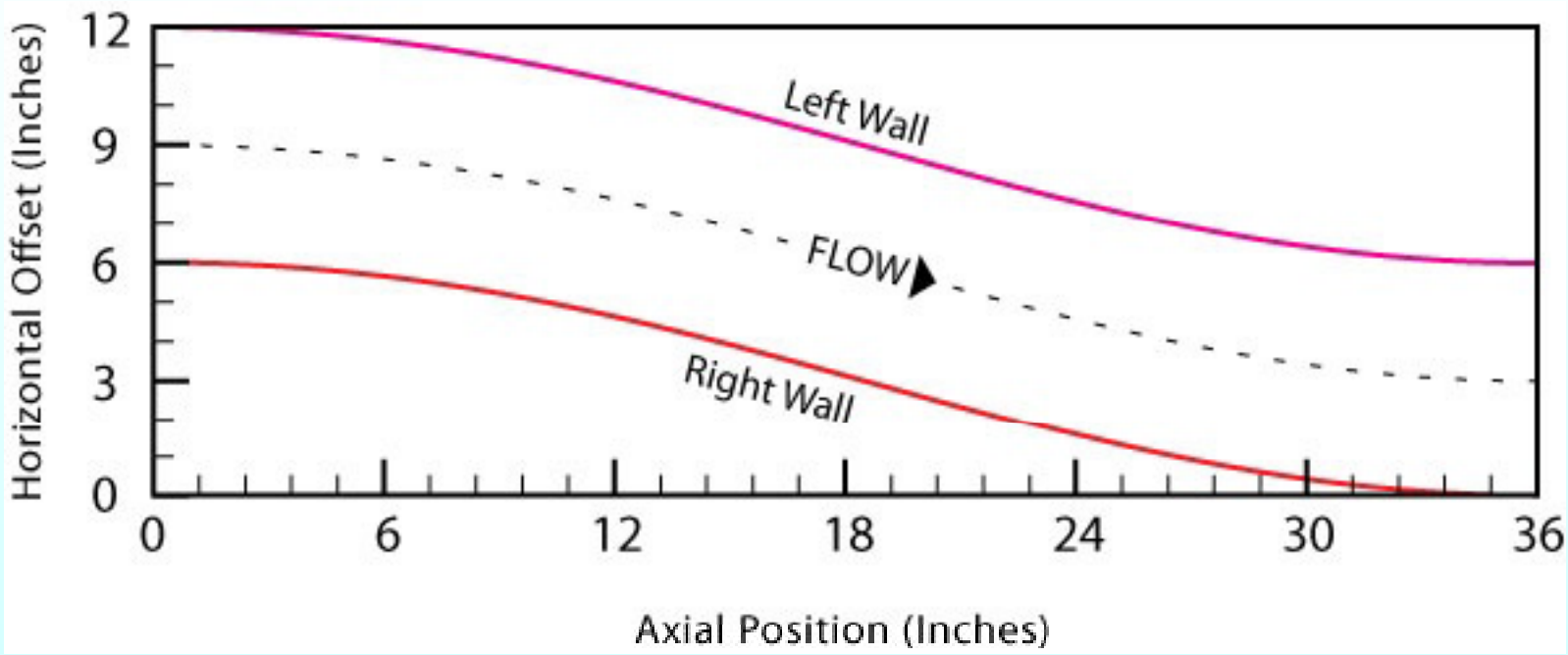
CDTR is valid tool for aerodynamic and acoustic evaluation of duct treatment

Thank you

Questions, Comments

Supplementary

Duct offset-1 D



CDTR cut on frequencies

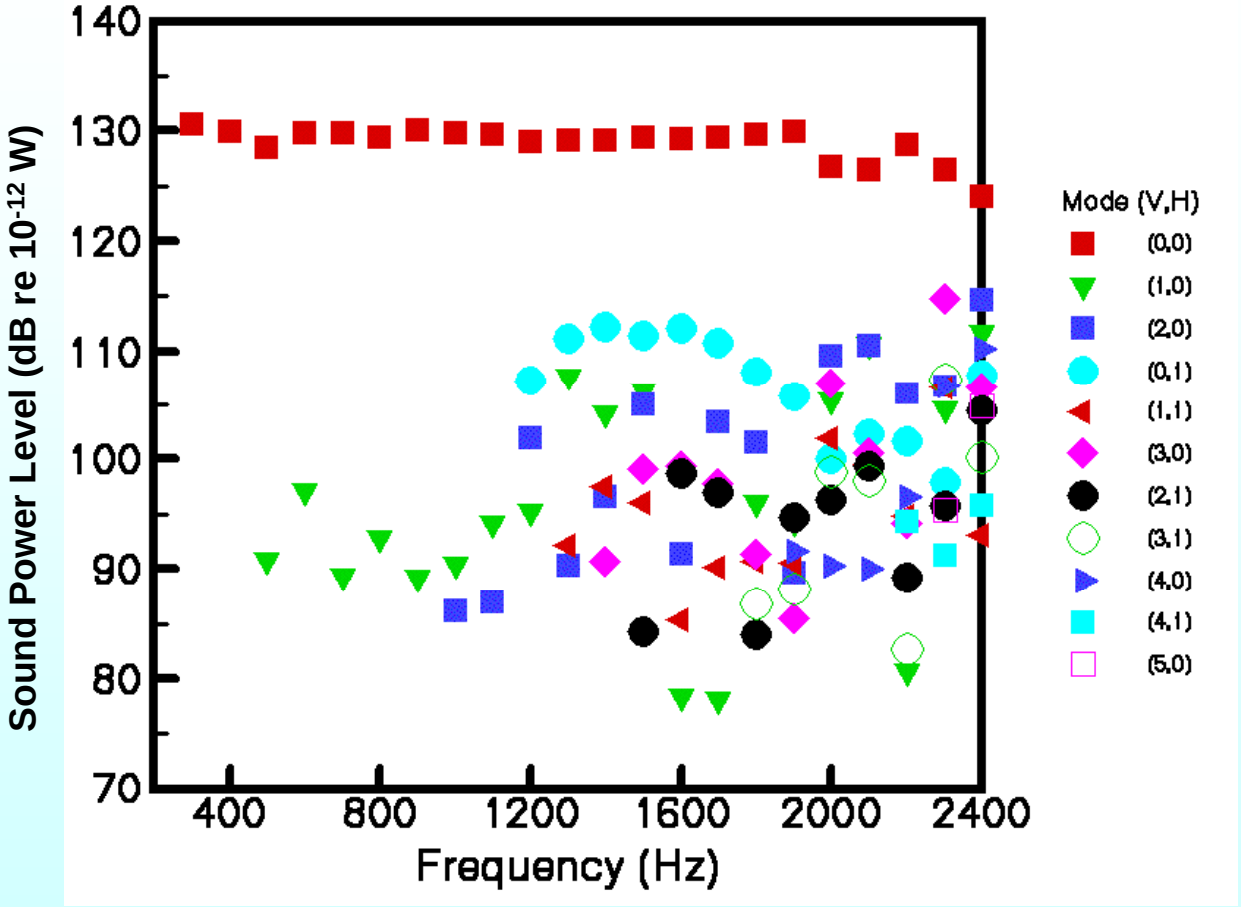
"Horizontal" order

"Vertical" order

m \ n	0	1	2
0	0	1128	2256
1	451	1215	2301
2	902	1445	2430
3	1354	1762	
4	1805	2128	
5	2256	2522	

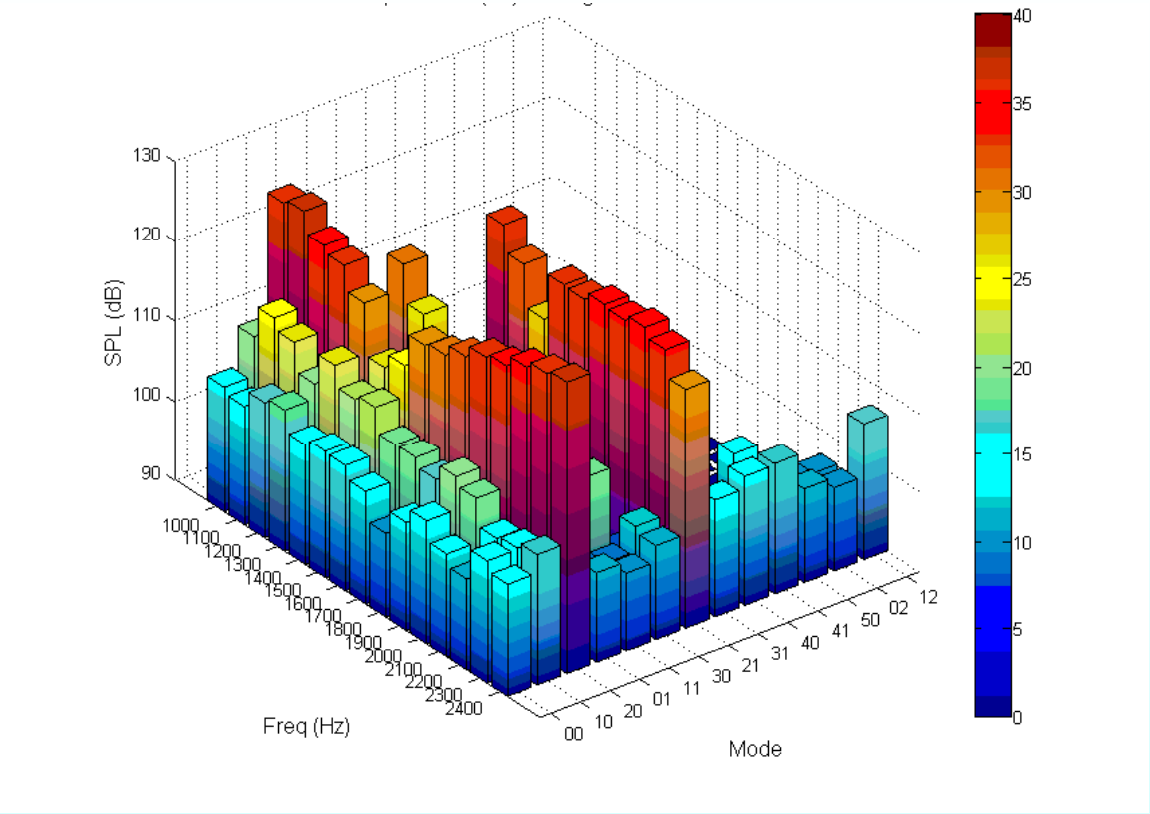
- **Flow speed: 0.00**
- **Temperature: 70°(F)**

Mode Isolation in CDTR



- **Generally greater than 20 dB mode separation from target mode**

Mode scattering-higher vertical mode



Mode distribution downstream, (2,0) mode generated in duct with curved liner

- **Horizontal 0-order mode scatters to horizontal 1-order mode**